Express Mail Label No.: EL 10909 US
Date Mailed: 3/31/2001

UNITED STATES PATENT APPLICATION FOR GRANT OF LETTERS PATENT

Brett T. Crawley
Jeroen Verheul
Danny Smit
Rene Andeweg
INVENTOR(S)

DEVICE AND METHOD FOR MONITORING A LASER-MARKING DEVICE

WITHROW & TERRANOVA, PLLC
P.O. Box 1287
Cary, NC 27512
(919) 654-4520

DEVICE AND METHOD FOR MONITORING A LASER-MARKING DEVICE

Field of the Invention

[0001] The present invention relates to laser marking systems that place markings onto products by emitting a laser beam.

Background of the Invention

[0002] Marking systems are used to place informative markings on products, typically during their manufacture and/or distribution. Informative markings include useful information about the product; for example, an expiration date, "born-on" date or date of manufacture, lot number, place of manufacture, and the like.

[0003] Laser-marking systems use a laser to place informative markings on products. A laser emits a laser beam that is directed to the product to etch informative markings onto the product. The laser beam may etch the surface of the product or a coating placed on the product beforehand. At times, laser-marking technology has certain advantages over other marking technologies, e.g., ink jet printing technology. For example, the maintenance of a laser equipment may be easier and more economical in certain circumstances than the maintenance of other types of markers. Since the laser marking technology does not depend on the use of an ink in a liquid state to produce a mark, it is less prone to printing problems caused by ink.

[0004] In addition, laser-marking technology allows marking of substrates at extremely high speeds. An example of the use of this technology is in the marking of expiration dates on plastic soda bottles. During laser marking, the rate of movement of

the conveyor carrying the soda bottles generally ranges from about 100 to 300 feet per minute, and it can be as high as 500 feet per minute.

[0005] It is important that laser-marking systems place informative markings onto products with a high rate of reliability. If products are not marked properly, such products may leave manufacturing and/or distribution facilities without the desired informative markings. When products moving at high speeds on an assembly line are marked, a product indicator may be used to detect the products as they pass in front of a marking laser. The laser emits a laser beam in response to a signal generated by the product indicator so that the laser beam is automatically emitted so as to precisely mark each product.

[0006] Occasionally, the marking laser may fail to emit a laser beam due to a malfunction or other problem. For example, the laser may have a dirty lens or other object blocking the laser beam path. However, in the event of such failure, the product indicator continues to detect products and trigger the laser to emit a laser beam. Absent some countermeasure, the laser-marking system will not detect a laser that is failing to emit a laser beam and mark products, and products will continue to move past the laser-marking system on the assembly line, potentially leaving the manufacturing and/or distribution facilities without the desired informative markings.

Summary of the Invention

[0007] The present invention relates to a laser-marking device and system that determines if a laser beam has been emitted in proper relation to a detected product. A product indicator produces a signal when it either detects a product in proximity to a

marking laser or is expecting a product to be in proximity to a marking laser. The marking laser emits a laser beam to place informative markings onto the product in response to this signal. A laser beam detector is placed in range of the laser beam to detect if the laser beam was emitted in proper relation to a signal from the product indicator. If the laser beam was not emitted in proper relation to the signal from the product indicator, an error output signal is generated.

[0008] In one laser beam detector embodiment, the laser beam detector is a thermal sensor that detects a temperature change (i.e. the presence or absence of heat). The thermal sensor is placed in proximity to the laser beam emitted by the laser-marking device.

[0009] In a second laser beam detector embodiment, the laser beam detector is comprised of an infrared emitter and detector. The infrared emitter and detector are placed on opposites sides of the laser beam path. If the infrared signal is passed through a laser beam, the infrared detector can detect a change in the infrared signal and generate a laser beam detection signal in response thereto. As one of ordinary skill in the art will appreciate, this embodiment may also be implemented by using a combination infrared emitter and detector wherein the emitter and detector reside in the same structure located on one side of the laser beam path.

[0010] In a third laser beam detector embodiment, the laser beam detector is a laser detector. The laser beam detector is placed in the expected path of the laser beam. Laser detector generates a laser beam detection signal in response thereto.

[0011] In a fourth laser beam detector embodiment, the laser beam detector is a thermocouple device. The thermocouple device is a thermocouple attached to a

glass window placed in the expected path of the laser beam. The thermocouple detects a change in heat of the glass window as the laser beam passes through the window and generates a laser beam detection signal in response thereto.

[0012] In a fifth laser beam detector embodiment, the laser beam detector is a sonic emitter and detector. The sonic emitter and detector are placed in the path of the laser beam, and the sonic emitter emits sounds waves towards the detector. The sonic detector can detect whether sound waves passed through the laser beam, and in response generate a laser beam detection signal.

[0013] A controller may be provided to determine if a laser has emitted a laser beam in proper relation to a product. The controller may include electronic circuitry, a micro-controller, or a microprocessor. The controller may also include memory, counters, and/or timers.

[0014] In one controller embodiment, a product indicator emits a product indication signal. A counter counts the product indication signals received and outputs the count into a flip-flop. The laser beam detector emits a laser beam detection signal when the laser beam is detected. If more than a selected amount of products are detected by the product indication signal without the laser beam detection signal resetting the counter and/or flip-flop, the flip-flop changes states and emits an error output signal to signify that the laser beam did not mark a product.

[0015] In a second controller embodiment, the product indication signal and laser beam detection signal are input into a first and second counter in the controller, respectively. The first counter counts the number of products detected, and the second counter counts the number of laser beams emitted by the laser. A microprocessor in

the controller compares the first counter and the second counter. If the values of the first and second counters differ by more than a threshold amount, the microprocessor generates an error output signal to signify that the laser beam did not mark a product(s).

[0016] In a third controller embodiment, a microprocessor in the controller uses a timer to record the time of receipt of both the product indication signal and the laser beam detection signal. The microprocessor determines if the time between the receipt of the product indication signal and the laser beam detection signal is greater than a threshold time value. If the time difference is greater than a threshold time value, the microprocessor generates an error output signal to signify that the laser beam did not mark a product(s).

[0017] The laser beam detection signal may also be coupled to a customer interface. The error output signal may also be coupled to a customer interface. The customer interface may include a counter to count the number of laser beam detection signals received. The value of this counter indicates the number of products marked with informative markings by the laser.

[0018] Alternatively, the product indication signal and the error output signal may also be coupled to a customer interface. The customer interface may include a counter to count the number of product indication signals received. The value of this counter indicates the number of products marked with informative markings by the laser, provided an error output signal is not received by the customer interface. The customer interface may also subtract the count of the error output signal counter from

the count of the product indication signal counter to determine the number of products marked with informative markings by the laser.

[0019] The error output signal may also be coupled to (1) a central controller that operates an assembly line transporting products through the laser-marking system and/or (2) the laser-marking system itself. If the central controller receives an error output signal, the central controller may stop the assembly line, stop the laser-marking system, alter the operation of either the assembly line or the laser-marking system, generate an alarm condition, and/or communicate the error output signal over a network to a remote system.

[0020] After the detection of an error output signal, the customer interface and/or central controller may also be designed to restart the assembly line after a reset indicator, located at the customer interface or at a remote location, is activated either manually by a user, in response to another system, and/or on the next valid laser-marking made onto a product.

Brief Description of the Drawings

[0021] Figure 1 is a schematic diagram of a laser-marking station;

[0022] Figure 2A is a schematic diagram of a thermal sensor and its field of view to detect temperature transitions;

[0023] Figure 2B is a schematic diagram of one thermal sensor temperature transition detection curve and related detection signal;

[0024] Figure 3A is a schematic diagram of an infrared emitter and detector;

[0025] Figure 3B is a schematic diagram of a laser detector;

[0026] Figure 3C is a schematic diagram of a thermocouple device;

[0027] Figure 3D is a schematic diagram of a sonic emitter and detector;

[0028] Figure 4 is a schematic diagram of a laser detection device with product indicator and customer interface;

[0029] Figure 5A is a schematic diagram of one controller embodiment comprising a counter and a J-K flip-flop;

[0030] Figure 5B is a truth table of the controller embodiment illustrated in Figure 5A;

[0031] Figure 6 is a schematic diagram of another controller embodiment comprising a microprocessor, memory, timer, and counter;

[0032] Figure 7 is a flowchart illustrating a technique to determine if a laser emitted a laser beam in proper relation to detection of a product; and

[0033] Figure 8 is a flowchart illustrating another technique to determine if a laser emitted a laser beam in proper relation to detection of a product.

Detailed Description of the Invention

[0034] The present invention relates to a device, system, and method for monitoring a laser beam that is used to place informative markings on products. Such informative markings may be placed on products during their manufacture and/or distribution. Informative markings may include any useful information concerning the product, including but not limited to, expiration date, "born-on" date or date of manufacture, lot number, and any other product information desired.

[0035] Figure 1 illustrates products 10 that are transported on an assembly line 12. A laser-marking station 14 is provided at a desired point on assembly line 12 where marking of products 10 is desired. A product indicator 16 detects the presence of product 10 as it begins to pass in front of laser-marking station 14. In this specific embodiment, product indicator 16 is comprised of an emitter 11 and a detector 13.

[0036] A laser 17 emits a laser beam 18 in response to product indication signal 19 (shown in Figure 4), generated by product indicator 16, to place informative markings on product 10. Laser-marking station 14 also includes a laser beam detector 20 that is placed proximate to the path of laser beam 18. Laser beam detector 20 detects whether laser 17 emitted laser beam 18 so that a laser detection device 40 (shown in Figure 4) may determine whether laser beam 18 was emitted onto product 10 in proper relation to the detection of product 10. Laser beam detector 20 may have a field of view 22 that detects all or an intersected portion 24 of laser beam 18.

[0037] In its broadest sense, "in proper relation" simply means that there is a correlation between a detected product 10 and the emission of laser beam 18. A laser 17 emits a laser beam 18 onto product 10 as product 10 is detected by product indicator 16. In particular, laser-marking station 14 causes laser 17 to emit laser beam 18 in response to detection of product 10 by product indicator 16. If laser beam 18 is emitted onto product 10 in proper relation to detection of product 10, there is a substantial likelihood that informative markings are placed on product 10 since there is a substantial likelihood that laser beam 18 struck product 10. The present invention is capable of determining whether or not laser beam 18 has been emitted in relation to each detected product 10, so that laser-marking station 14 can take any appropriate

actions desired to ensure that laser beam 18 is emitted onto products 10 as products 10 are detected. Such determination may be accomplished by counting detected products 10 in relation to detected laser beam 18 emissions, or errors generated by laser marking station 14. Timings of detected product 10 and detected laser beam 18 may also be used for such determination.

[0038] Product indicator 16 may be any type of sensor that can detect the physical presence of an object, such as product 10, as it moves in front of laser-marking station 14. Product indicator 16 emits a product indication signal 19 when product 10 is detected. Product indicator 16 may be a proximity sensor, including but not limited to the proximity sensors discussed in U.S. Patent Nos. 5,675,173; 5,877,664; 5,880,538, all of which are incorporated herein by reference in their entirety. Product indicator 16 may be an infrared emitter 11 and detector 13, as illustrated in Figure 1 and discussed in U.S. Patent No. 5,675,150, entitled “Active IR intrusion sensor,” incorporated herein by reference in its entirety. Product indicator 16 may be a sonic sensor that uses sound waves to detect product 10. Product indicator 16 may also include a switch that is activated upon detection of product 10.

[0039] In an alternative embodiment, product indicator 16 may be an indication of an expected time when product 10 is expected or predicted to be in front of the laser-marking station 14 rather than a physical detection device. For example, product indicator 16 may be a clock signal that is generated from the movement of assembly line 12 (e.g., an encoder). As assembly line 12 moves in front of laser-marking station 14, a mechanical device may be attached to assembly line 12 to generate electronic pulses at the movement rate of assembly line 12. Or a detection device may generate

a signal or electronic pulses for every portion of a predetermined length assembly line 12 where a product 10 is expected on assembly line 12. Any type of indicator may be used for product indicator 16, and the present invention is not limited to any particular indicator or method of detecting product 10.

[0040] Laser 17 projects laser beam 18 through a system of optics (not shown) that typically includes lenses and masks. The optics are controlled by a control system (not shown) to direct laser beam 18 to the desired area on product 10 for marking. Laser beam 18 contacts product 10 at different locations, as directed by the optics and the control system, to produce the desired informative markings on product 10. Any type of laser 17, including a carbon dioxide laser or YAG laser, may be used with the present invention, and the present invention is not limited to any particular type of laser 17. U.S. Patent No. 4,652,722, entitled "Laser marking apparatus," incorporated herein by reference in its entirety, discusses a particular laser 17 arrangement and laser-marking station 14 that may be used with the present invention if product indicator 16, laser beam detector 20, and a laser detection device 40 are additionally provided.

[0041] A coating material (not shown) may be placed on product 10 before marking, and the laser beam 18 may irradiate the coating material instead of the product 10. U.S. Patent No. 5,294,774, entitled "Laser marking system," later reissued in U.S. Reissue Patent No. RE35,446, both of which are incorporated herein by reference in their entirety, disclose different coating materials that may be placed on products 10 to be marked by laser 17.

[0042] Figures 2 and 3 illustrate various types of laser beam detectors 20 that may be used with the present invention, and the present invention is not limited to any

particular type or embodiment. Figure 2A illustrates one type of laser beam detector 20 known as a thermal sensor 20A. A thermal sensor 20A detects transitions in temperature. A hot to cold or cold to hot transition may be detected depending on the particular type of thermal sensor 20A and its designed operation. Thermal sensor 20A has a field of view 22. As heat enters the field of view 22, thermal sensor 20A detects the heat from laser beam 18 and trigger an internal thermal switch. Because laser beam 18 generates heat, thermal sensor 20A can detect laser beam 18 if it enters in its field of view 22, including any intersected portion 24 of laser beam 18 and field of view 22. Thermal sensor 20A may be placed on laser-marking station 14 so that its field of view 22 is in the expected path of laser beam 18, or thermal sensor 20A may be placed proximate to product 10 in close proximity to where laser beam 18 is expected to hit product 10.

[00043] Figure 2B illustrates a line graph of a temperature transition detected by thermal sensor 20A. A laser beam temperature line 25 indicates a detection of a cold to hot temperature transition by thermal sensor 20A when laser beam 18 is in the field of view 22. If the rate of change of temperature detected by thermal sensor 20A is "significant," thermal sensor 20A causes a trigger in the thermal switch, included in thermal sensor 20A, to output a switch indicated by the laser beam detection signal 26. The relevant "significant" change in temperature may be configured to be any amount of temperature desired, including small temperature change transitions depending on the type of thermal sensor 20A and its capabilities of detecting change in temperature.

[0044] Thermal sensor 20A may also be able to determine if laser 17 has lost power or has any attenuation preventing it from emitting a laser beam 18 at full

strength. Laser 17 may have a blocked filter or lens or may have internal problems that cause laser beam 18 to be attenuated in either power or field of range. In either case, thermal sensor 20A may still detect a temperature change, but such temperature change may be less than expected for the particular laser 17 used in laser-marking station 14. In such a case, laser beam detector 20 may be able to generate a laser beam detection signal 26 that is indicative of such a condition.

[0045] In one thermal sensor 20A embodiment, thermal sensor 20A is manufactured by Exergen, Inc. under the name SnakeEye™. Descriptions of Snake Eye™ can be found at http://www.exergen.com/industrl/spdboost/slidesho/sld047.htm, http://www.exergen.com/industrl/slides/sld038.htm, and http://www.exergen.com/industrl/product/html/snakeyet.htm, all of which are incorporated herein by reference in their entirety.

[0046] Figure 3A illustrates another type of laser beam detector 20 known as an infrared emitter and detector 20B. Infrared emitter and detector 20B is comprised of an infrared emitter 30 and infrared detector 36. Infrared emitter 30 emits an infrared signal 34 through a transparent window 32 to the path of laser beam 18. Infrared detector 36 is located opposite to infrared emitter 30 to pick up infrared signal 34 emitted by infrared emitter 30. Infrared detector 36 also includes a transparent window 38 so that infrared signal 34 can penetrate and go into infrared detector 36. If laser beam 18 does not pass through the path of infrared signal 34, infrared detector 36 will detect an unaltered infrared signal 34. However, if laser beam 18 does pass through the path of infrared signal path 34, infrared detector 36 will detect a change or alteration in infrared signal 34. Infrared detector 36 may then emit a signal or other type of

detection, in the form of a laser beam detection signal 26, to indicate that laser 17 emitted laser beam 18. An example of an infrared emitter and detector 20B that may be used with the present invention is discussed in U.S. Patent No. 5,675,150, entitled "Active IR intrusion detector," previously incorporated herein by reference in its entirety.

[0047] Infrared emitter 30 may be a solid state or black body radiator. Infrared detector 36 may be a solid-state device of pyro-electric infrared (PIR) device. Note that the laser beam detector 20 may use an emitter and detector that emits and detects a different type of signals other than infrared. For example, the signal emitted and detected may be in the visible spectrum.

[0048] Further, one of ordinary skill in the art will appreciate that infrared emitter 30 and infrared detector 36 may be combined in the same structure (not shown). In such a configuration, infrared detector 36 detects the amount of infrared signal 34 emitted by infrared emitter 30 that is reflected back to the structure containing emitter 30 and detector 36. Similar to the above embodiment, detector 36 will detect an altered infrared signal 34 if laser beam 18 passes through the path of infrared signal 34.

[0049] Figure 3B illustrates another type of laser beam detector 20 that comprises a laser detector 20C. Detector 20C directly detects the laser beam 18 emitted from laser 17. Detector 20C may be any type of detector that can detect a laser beam 18. In one embodiment, detector 20C is an infrared detector similar to the detector illustrated in Figure 3A. Detector 20C may have a detector 36 that includes a transparent window 38 so that light from laser beam 18 may pass through transparent window 38 into detector 36. Detector 36 may then emit a signal or other type of indicator, in the form of a laser beam detection signal 26 to indicate that laser 17

emitted laser beam 18. Detector 20C may be placed anywhere proximate to assembly line 12 and/or products 10 so that laser beam 18 is directed in whole or part into detector 20C when laser beam 18 marks product 10.

[0050] Figure 3C illustrates another type of laser beam detector 20 known as a thermocouple device 20D. Thermocouple device 20D is comprised of a glass window 39 and a thermocouple sensor 41. Glass window 39 is placed in the path of laser beam 18 so that laser beam 18 will pass through glass window 39 on its way to marking a product 10. Theremocouple sensor 41 detects heat. When laser beam 18 passes through glass window 39, thermocouple sensor 41 detects the heat from laser beam 18 and emits a signal or other type of indicator in the form of a laser beam detection signal 26 to indicate that laser 17 emitted laser beam 18.

[0051] Figure 3C illustrates another type of laser beam detector 20 known as a sonic emitter and detector 20E. Sonic emitter and detector 20E includes an emitter 43 that emits sound waves 45, and a detector 47 that picks up the sound waves. Sonic emitter and detector 20E are placed apart so that laser beam 18 passes through the sounds waves 45. If sound waves 45 are emitted by emitter 43 through ambient air, detector 47 will detect sound waves in one form. If sound waves are emitted by emitter 43 through the path of laser beam 18, detector 47 will detect sound waves 45 in a different form than when sound waves 45 pass through ambient air. The difference in form is detected and laser beam detection signal 26 is produced, to indicate that laser 17 emitted laser beam 18.

[0052] The present invention may use any type of laser beam detector 20 so long as it can detect if laser 17 emitted laser beam 18, either directly by sensing laser

beam 18, or indirectly by sensing characteristics of the laser 17 (e.g., the presence of heat). The present invention is not limited to any particular type of laser beam detector 20.

[0053] Figure 4 illustrates one embodiment of a laser detection device 40. Laser detection device 40 determines if laser beam 18 was emitted onto product 10 in proper relation to product indicator 16. Laser detection device 40 is comprised of laser beam detector 20 and controller 42. Controller 42 may be comprised of basic electronic circuitry, more complex electronic circuitry, or even a micro-controller or microprocessor, whereby additional supporting hardware and/or software may be present.

[0054] In this embodiment, controller 42 accepts as input laser beam detection signal 26 from laser beam detector 20, and product indication signal 19 from product indicator 16. Controller 42 inputs may be optically isolated for each other. Controller 42 determines whether laser 17 emitted laser beam 18 in proper relation to product indication signal 19. If controller 42 determines that laser beam 18 was not emitted in proper relation to product indication signal 19, controller 42 emits an error output signal 46. Error output signal 46 can be used to perform various tasks. Controller 42 inputs and output may also be optically isolated from each other.

[0055] Error output signal 46 may also be used to indicate an error on a customer interface 44. Customer interface 44 can be any type of display, such as a Cathode Ray Tube (CRT) or Liquid Crystal Display (LCD), visual and/or audio alarm, or other visual and/or audio device to indicate the presence of error output signal 46.

[0056] Error output signal 46 may be used to signal a central controller (not shown) that controls the operation of assembly line 12 and/or laser-marking station 14. The central controller may be a programmable logic controller (PLC) or other control device or system. The central controller may control operation of assembly line 12, such as power to assembly line 12, and/or operation of laser-marking station 14. The central controller may shut down operation of assembly line 12 upon receiving an error output signal 46 until laser 17 is checked and/or repaired, if needed. The central controller may send a signal to another system at a remote location from assembly line 12 and laser-marking station 14 in the event that operation of assembly line 12 and/or laser-marking station 14 is monitored remotely.

[0057] Laser beam detection signal 26 may be used to count products 10 marked by laser beam 18. Laser beam detection signal 26 indicates the number of products 10 marked by laser beam 18. The total count of products 10 likely marked by laser beam 18 is the count of the number of laser beams 18 detected by laser beam detection signal 20. Thus, the laser beam detector 20 may be coupled to a counter to count the laser beam detection signals 26. Such counter may optionally be included in controller 42, in customer interface 44, or any other system that has laser beam detection signal 26 as an input.

[0058] Alternatively, the number of products 10 marked by laser beam 18 could be calculated using product indication signal 19. Controller 42 and/or customer interface 44 may subtract error output signal 46 from product indication signal 19 to represent the number of products 10 detected that were marked by laser beam 18. Controller 42 and/or customer interface 44 may use one or more counters to count the

error output signal 46 and/or the product indication signal 19 to perform such calculation. Further, the necessary counters may be located in any other system that has product indication signal 19 and error output signal 46 as inputs.

[0059] Figures 5A and 5B illustrate one embodiment of controller 42 that may be used with the present invention. Controller 42 is comprised of electronic circuitry, including a 4-bit binary counter 50, for a total of sixteen unique states, and a J-K flip-flop 52. Product indication signal 19 is coupled to an input on counter 50. Product indication signal 19 is an input signal that transitions from either high to low or low to high for every product 10 detected. Counter 50 transitions to a next counting state for each clock cycle that product indication signal 19 is present on the input of counter 50. If product indication signal 19 is present for subsequent clock signals without interruption, and/or without being reset, counter 50 will continue to transition count states such that, for example, Vcc or "1" is present on C1, C2 on the second cycle, C3 on the fourth clock cycle, and C4 on the eighth clock cycle. Once counter 50 reaches its sixteenth state, in which C0, C1, C2, and C3 are all Vcc or "1", counter 50 begins again at the first state wherein C0 is Vcc or "1.".

[0060] In this particular embodiment, counter 50 is capable of counting sequentially in sixteen different states until reset. The C2 line of counter 50 is coupled to a clock on J-K flip-flop 52. Note that the circuit illustrated in Figure 5A may include user-selectable jumper connections for the connection of any C line to the clock input on J-K flip-flop 52, including C0, C1, C2, and C3. The J input is coupled to Vcc or "1," and the K input is coupled to ground, or "0," so that J input and K input are always high (Vcc or "1") and low (ground or "0"), respectively. Output Q is the port that outputs a

state change in J-K flip-fop 52. Laser beam detection signal 26 is coupled to the reset of counter 50 and optionally to the reset of J-K flip-flop 52. Every time product indication signal 19 is received in proper relation to laser beam detection signal 26, counter 50 and J-K flip-flop 52 (if laser beam detection signal 26 is coupled to the reset of J-K flip-flop 52) are reset so that counter 50 and J-K flip-flop 52 never transition to their next state. J-K flip-flop 52, when reset, is in a zero state transition for output Q. The reset of counter 50 and/or J-K flip-flop 52 may be controlled by a manually activated switch so that counting does not begin again until desired. For example, error output signal 46 may stop assembly line 12, and the counting should not be restarted until the assembly line 12 is once again operational.

[0061] In the illustrated embodiment, if product indication signal 19 is received in four consecutive clock cycles without counter 50 and/or JK flip-flop 52 being reset by laser beam detection signal 26, C2 will become Vcc or "1" on the fourth product indication signal 19 received. Vcc or "1" present on C2 causes J-K flip-flop 52 to transition to the next state, thereby causing output Q to become a "1" or Vcc. Output Q is coupled to error output signal 46.

[0062] Figure 5B illustrates a chronological truth table for the circuit configuration illustrated in Figure 5A for four consecutive clock cycles where product 10 is detected, but the laser beam 18 is not detected. The product indication signal is "1" for each clock cycle 1-4. C2 of counter 50 is "1" when the fourth product indication signal 19 received. J input on J-K flip-flop 52 is always "1." K input on J-K flip-flop 52 is always "0." When C2 is "1," on the fourth clock cycle, J-K flip-flop 52 is clocked and

transitions to the next state. Q output of J-K flip-flop 52 transitions from a "0" to a "1," thereby causing error output signal 46 to indicate an error.

[0063] Please note that the circuit illustrated in Figure 5A can be configured to generate error output signal 46 after one or more consecutive laser beam detection signals 26 are not received in proper relation to product indication signal 19. For example, C1 would be used to input into the clock of J-K flip-flop 52 if error output signal 46 where to be generated after two consecutive laser beam detection signals 26 were not received in proper relation to product indication signal 19. A different type of flip-flop, such as an S-R or D flip-flop, may be used with the present invention. The present invention is not limited to a laser beam 18 being detected in proper relation to any particular number of consecutive products 10.

[0064] Figure 6 illustrates another embodiment of controller 42. In this embodiment, controller 42 comprises more complex circuitry that includes a microprocessor 54. Controller 42 includes an input buffer 56 and an output buffer 58. Laser beam detection signal 26 and product indication signal 19 are received by input buffer 56. Input buffer 56 passes such signals to microprocessor 54. Microprocessor 54 is coupled to output buffer 58 to generate error output signal 46 when laser 17 does not emit laser beam 18 in proper relation to product indication signal 19. Controller 42 also includes memory 60, timer 62 and/or counter 64 that are all coupled to microprocessor 54. Two counters 64A, 64B (not shown) may optionally be provided to count both product indication signal 19 and laser beam detection signal 26.

[0065] Figure 7 illustrates a process flowchart of one embodiment of controller 42 of Figure 6. The process starts (block 100) and microprocessor 54 initializes

counter(s) 64 to zero (block 101). Microprocessor 54 increments first counter 64A (not shown) when product indication signal 19 is received through input buffer 56 (block 102). Microprocessor 54 increments second counter 64B (not shown) when a laser beam detection signal 26 is received through input buffer 56 (block 104). Microprocessor 54 compares the value of first counter 64A to the value of second counter 64B (decision 106). If the value of first counter 64A is greater than the value of second counter 64B by more than a threshold value, microprocessor 54 generates error output signal 46 through output buffer 58 (block 108), and the process ends (block 110). If the value of first counter 64A is not greater than the value of second counter 64B by a certain threshold value, the process continues by returning to block 102.

[0066] The threshold value may be a count of one or greater. The threshold value is the number of products 10 that are not in proper relation to laser beam 18 emissions that may be detected by controller 42 before error output signal 46 is generated. The threshold value may be stored in memory 60 or may be provided through use of circuitry, such as the jumper configuration previously discussed.

[0067] Figure 8 illustrates another flowchart of a possible operation of controller 42 of Figure 6. The process starts (200), and microprocessor 54 uses timer 62 to store the time (Time 1) when product indication signal 19 is received from input buffer 56 (block 202). Microprocessor 54 also uses timer 62 to store the time (Time 2) when laser beam detection signal 26 is received from input buffer 56 (block 204). Microprocessor 54 subtracts Time 1 from Time 2 to obtain a time difference (block 205) and then determines if this time difference value is greater than a threshold value (decision 206). If so, microprocessor 54 generates error output signal 46 through

output buffer 58 (block 208), and the process ends (block 210). If the threshold value is not exceeded, the process continues by returning to block 202.

[0068] The threshold time may be in nanoseconds, microseconds, milliseconds, or seconds depending on the speed of assembly line 12 and the rate at which products 10 pass laser-marking station 14. The threshold time may be stored in memory 60 or through use of circuitry, such as a jumper configuration. For example, a typical threshold time may be as low as around about 50 milliseconds and as high as around about 1 second, depending on the speed at which products 10 are transported on assembly line 12.

[0069] Certain modifications and improvements will occur to those skilled in the art upon a reading of the foregoing description. It should be understood that the present invention is not limited to any particular type of product 10, laser-marking station 14, product indicator 16, laser 17, laser beam detector 20, controller 42, or particular electronic circuitry comprising controller 42, type of counter 50 and flip-flop 52, threshold number of products 10 detected without detection of laser beam 18, and threshold amount of time between detection of products 10 and detection of laser beam 18. In addition, it should be understood that for purposes of this invention as described herein, couple or coupled includes connected, whether directly connected or connected through some other form, such as wireless communication, infrared, and optical signaling, or reactively coupled, whether by capacitance or inductance.

[0070] One of ordinary skill in the art will recognize that there are different manners in which the elements discussed above can be configured to operate to accomplish the present invention. The present invention is intended to cover what is

claimed and any equivalents. The specific embodiments used herein are to aid in the understanding of the present invention, and should not be used to limit the scope of the invention in a manner narrower than the claims and their equivalents.